We claim:

1. A method for improving a thermal barrier coating comprising:

providing a substrate;

providing a nanocrystalline, nano-composite bond coat on the substrate; and

providing a ceramic top coat on the nanostructured nano-composite bond coat.

2. The method of claim 1 where providing the bond coat on the substrate and providing a nanocrystalline nano-composite coating comprises providing a bond coat composed of nanocrystalline MCrAlY, where M stands for either Co, Ni and/or Fe, using a thermal spray process onto a metallic substrate, and where providing the ceramic top coat on the nanostructured, nano-composite bond coat comprises providing a yttria partially stabilized Zirconia (YPSZ) ceramic top coat on the nanostructured, nano-composite bond coat.

3. The method of claim 2 where the providing the nanocrystalline, nano-composite coating comprises providing a Ni/Cr/Al/Y system (balance:22:10:1 respectively by wt.%) bond coat disposed on a Ni-based alloy substrate using a high velocity oxy fuel (HVOF) thermal spray process or low pressure plasma spray process (LPPS).

4. The method of claim 2 where providing the nanocrystalline, nano-composite coating comprises cryomilling a NiCrAlY powder and thermally spraying the cryomilled NiCrAlY powder onto the substrate in the presence of oxygen.

5. The method of claim 4 where cryomilling the NiCrAlY powder comprises cryomilling the powder in a liquid nitrogen environment.

6. The method of claim 4 where cryomilling the NiCrAlY powder comprises cryomilling the NiCrAlY powder for at least 8 hours.

7. The method of claim 1 where providing the nanocrystalline, nano-composite coating comprises cryomilling a MCrAlY powder in the presence of oxygen, where M stands for either Co, Ni and/or Fe, such that aluminum oxide is formed in the cryomilled powder to serve as a nucleation site for further alumina formation in the top coat and using a high velocity oxy fuel (HVOF) thermal spray process or low pressure plasma (LPPS) spray process to deposit the cryomilled powder onto the substrate.

8. The method of claim 7 where providing the nanocrystalline, nano-composite coating comprises thermal spraying in the presence of oxygen to further form aluminum oxide in the sprayed bond coat.

9. The method of claim 8 where providing the nanocrystalline, nano-composite coating comprises heat treating the sprayed substrate in the presence of oxygen to induce a thermally grown oxide layer (TGO) thereon.

10. The method of claim 9 where heat treating the sprayed substrate in the presence of oxygen to induce a thermally grown oxide layer (TGO) comprising inducing the formation of a continuous α-Al_2O_3 layer on the top of the bond coat.

11. The method of claim 1 where providing the nanocrystalline alumina coating comprises cryomilling an alumina powder to achieve nanocrystalline grain sizes and disposing the cryomilled nanostructured alumina composite coating on the bond coat.

12. The method of claim 11 where disposing the alumina powder on the bond coat comprises plasma spraying the nanocrystalline alumina powder onto the bond coat in the presence of oxygen.

13. A thermal barrier coating comprising:

a substrate;

a nanocrystalline, nano-composite bond coat on the substrate; and

a ceramic top coat on the nanostructured, nano-composite bond coat.

14. The thermal barrier coating of claim 13 where the bond coat on the substrate comprises a bond coat composed of nanocrystalline MCrAlY, where M stands for either Co, Ni and/or Fe, using a high velocity oxy fuel (HVOF) thermal spray process or low pressure plasma (LPPS) spray process onto a metallic substrate, and where the ceramic top coat on the nanostructured nano-composite bond coat comprises a Yttria partially stabilized zirconia (YPSZ) ceramic top coat on the nanostructured nano-composite bond coat.

15. The thermal barrier coating of claim 14 where the nanocrystalline nano-composite coating comprises a Ni/Cr/Al/Y system (balance:22:10:1 respectively by wt.%) bond coat disposed on a Ni-based alloy substrate using the high velocity oxy fuel (HVOF) thermal spray process or low pressure plasma (LPPS) spray process.

16. The thermal barrier coating of claim 14 where the nanocrystalline nano-composite coating comprises a cryomilled NiCrAlY powder which is thermally sprayed onto the substrate in the presence of oxygen.

17. The thermal barrier coating of claim 16 where the cryomilled NiCrAlY powder comprises a powder cryomilled in a liquid nitrogen environment.

18. The thermal barrier coating of claim 16 where the cryomilled NiCrAlY powder comprises a NiCrAlY powder which has been cryomilled for at least 8 hours.

19. The thermal barrier coating of claim 13 where the nanocrystalline nano-composite coating comprises a MCrAlY powder cryomilled in the presence of oxygen, where M stands for either Co, Ni and/or Fe, such that aluminum oxide is formed in the cryomilled powder to serve as a nucleation site for further alumina formation in the top coat and which cryomilled powder is disposed onto the substrate using a high velocity oxy fuel (HVOF) thermal spray process.

20. The thermal barrier coating of claim 19 where the nanocrystalline nano-composite coating comprises a thermal sprayed bond coating which is sprayed onto the substrate in the presence of oxygen to further form aluminum oxide in the sprayed bond coat.

21. The thermal barrier coating of claim 20 where the bond coat and nanocrystalline nano-composite coating comprises a sprayed bond coat which has further been heat treated in the presence of oxygen to induce a thermally grown oxide layer (TGO) thereon.

22. The thermal barrier coating of claim 21 where heat treated nano-composite bond composite has a continuous α-Al_2O_3 layer on the bond coat.

23. The thermal barrier coating of claim 13 where the nanocrystalline nano-composite coating comprises a cryomilled alumina powder which has been sufficiently cryomilled to achieve nanocrystalline grain sizes.

24. The thermal barrier coating of claim 23 where the nanocrystalline nano-composite coating is further plasma sprayed onto the bond coat in the presence of oxygen.

25. A method for improving a MCrAlY thermal barrier coating made from MCrAlY powder, where M is a metal or metal alloy, comprising:

providing a MCrAlY bond coat on a substrate; and

providing a nanocrystalline nano-composite coating on the MCrAlY bond coat with a nanostructured nano-composite-bond coat by refining the microstructure of the MCrAlY powder to nanocrystalline grain size.

26. The method of claim 25 further comprising providing a ceramic top coat on the nanostructured nano-composite-bond coat.

27. The method of claim 25 where refining the microstructure of the MCrAlY powder to nanocrystalline grain size comprises cryomilling the MCrAlY powder during which the microstructure of the MCrAlY powder is refined to nanocrystalline grain size through the *in-situ* formation of oxides, nitrides and/or oxynitrides.

28. The method of claim 25 where refining the microstructure of the MCrAlY powder to nanocrystalline grain size comprises cryomilling the MCrAlY powder and refining the microstructure of the MCrAlY powder to nanocrystalline grain size during cryomilling through the introduction of Al_2O_3 particles during cryomilling.

29. The method of claim 28 where refining the microstructure of the MCrAlY powder to nanocrystalline grain size during cryomilling comprises introducing nano alumina particles during cryomilling.

30. The method of claim 28 where refining the microstructure of the MCrAlY powder to nanocrystalline grain size after cryomilling comprises introducing nano alumina whiskers during cryomilling.

31. A MCrAlY thermal barrier coating made from MCrAlY powder, where M is a metal or metal alloy, comprising:

a MCrAlY bond coat on a substrate; and

a nanostructured nano-composite bond coat with nanocrystalline size MCrAlY grains.

32. The thermal barrier coating of claim 31 further comprising a ceramic top coat on the nanostructured nano-composite-bond coat.

33. The thermal barrier coating of claim 31 where the nanocrystalline size MCrAlY grains are formed by cryomilling the MCrAlY powder during which the microstructure of the MCrAlY powder is refined to nanocrystalline grain size through the *in-situ* formation of oxides, nitrides and/or oxynitrides.

34. The thermal barrier coating of claim 31 where the powder nanocrystalline size MCrAlY grains are formed by cryomilling the MCrAlY powder and refining the microstructure of the MCrAlY powder to nanocrystalline grain size after cryomilling through the introduction of Al_2O_3 particles during cryomilling.

35. The thermal barrier coating of claim 34 where the nanocrystalline size MCrAlY grains formed after cryomilling arise from nano alumina particles introduced during cryomilling.

36. The thermal barrier coating of claim 34 where the nanocrystalline size MCrAlY grains formed after cryomilling arise from nano alumina whiskers introduced during cryomilling.